Modelling of Relation Between large Earthquakes and Ionosphere Electron Density Using GPS Data (case study: Azerbaijan Earthquakes)

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Abstract:

The ionosphere is a part of the earth's atmosphere, laying at the heights between 50 km and 2000 km above the earth's surface, and consisting of several layers identified by differences in the level of ionization. GPS ionospheric error consists of the satellite signal propagation delay collected during the passage of the ionosphere. The GPS ionospheric time-delay is directly proportional to the number of electrons per unit area encountered during the passage of the ionosphere, usually referred to as the total electron content (TEC). TEC is a projection of electron density along signal path extending from the satellite to the receiver on the ground. The unit of TEC is TECU and 1 TECU equals 10^{16} electrons/m^2. With the creation of local and regional networks, it is possible to acquire TEC in regular ionospheric grids. Using the regular ionospheric grids, the prediction of TEC in other parts of network is possible. Once the TEC is predicted, it is possible to correct ionospheric refraction in single frequency GPS receiver. In the customary two dimensional modeling techniques, ionosphere is approximated by a thin spherical shell of free electrons, located; 250 to 450 Km from the surface of the earth. The existing two dimensional methods of modeling the electron density can be classified to non-grid based and grid based techniques. The former modeling techniques are based on the least squares estimation of a functional model for certain types of observables derived from the GPS carrier phase and code measurements. So far, several different interpolation methods are used to predict TEC values. Spherical harmonics, spline interpolation, Gaussian processes are some of the examples used methods to predict TEC values for the locations where physical data are not exist. National cartographic center of Iran (NCC) is completing the Iranian permanent GPS network for geodynamics (IPGN). This network facilitates better understanding of tectonic deformation which allows estimating of future hazards and promoting scientific knowledge. The network consists of two parts: a) base network that covers the entire country of Iran, consisting of 41 GPS stations and b) three local networks in the most populated and active zones. The local networks are established in Tehran, Azerbaijan, and Khorasan with critical tectonic activities. GPS measurements of 12 successive days in August 2012 (DOY#219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229 and 230) have been used for modeling and processing. VTEC values at a temporal resolution of 15 min were derived from the dual frequency GPS receivers. According to results, it can be easily deduced that there are temporal variations in the electron content of the ionosphere. The characteristics which are the constituents of the ionosphere morphology are also reported elsewhere and confirmed by the analysis of the direct measurement techniques. The diurnal pattern of TEC exhibited a steady decrease from DOY#220. This decline has occurred at all hours. Also using these results can be clearly seen that the maximum value of TEC observed in daytime (8 UT), while the lowest occurred at nighttime (4 UT). It should be noting that at 2012/08/12 (DOY#224), the earthquake (M_w=6.4) occurred in this area. Based on the studies on impact of the earthquake in the value of TEC and ionosphere electron density, perhaps, earthquake is the main reason for reducing the value of TEC.

Keywords: Earthquake, TEC, GPS, IRI2012, Ionosphere

1- Introduction

Human long for a way to predict natural disasters to avoid casualties and financial losses incurred by it on the body of its own. In this connection the earthquake as one of the most deadly poison and the most destructive disasters of interest to scientists and researchers and many research carried out in this respect, it is of course accepted in many cases due to the deficiency of knowledge in this area to a convincing results have not yet been interconnected.

Prior to the occurrence of great earthquakes, one can induce changes in the physical and chemical characteristics of the atmosphere of the Earth view. We can change such parameters of electrical conductivity rate has barley (kometjani ., ۱۹۹۷), the amount of radon level and density of various layers of electron and height insofar. One of these changes in this article will be assessed, changes in density or density of the free electronic in the ionosphere layer of the atmosphere. Among the various parameters which has undergone change before the earthquake, according to different parameters, change the ionosphere that occurs before the earthquake is less history. The first time in the 1964 Alaska earthquake with Magnitude 2.9 Richter measured on the scale to be bound before the earthquake struck, attention in the ionosphere. Analysis of measurements performed at the ionusond stations shows that hours before the earthquake in ionosphere mark is visible (bolt, 1964). In the required analysis done in conjunction with the earthquake due to the critical frequency values of data deficiency in the F2 layer for two years, 143 days and on the day before the earthquake it has compared the local changes in the center of the earthquake near F2 studied in the days before the earthquake shows. This study was the origin of most of the reviewer in the futures tour (Ghodsi and mashadi h., 2011).

After the Alaska earthquake studies on the different parameters in the different layers of the ionosphere, who were undergoing changes. Initial studies were done, they were the only perception, they did so gradually that the advancement of science and technology in various scientific theories, and they were raised with these observations. Among the changes undergone in the ionosphere parameters before the earthquake can be critical to the study of changes in frequency in the E layer. Antslvich at first and after he, Datchanco and partners to the study of these changes in relation to the earthquake that happened in 1966 Tashkent. They were successful with the relative changes in the critical frequency gain E layer ionosphere to see the earthquake precursors (Abdullahi et al., 2004). Also, at first the Russians and then the Japanese to study changes in the D layer. The first related to the experimental in form D layer under the influence of the earthquake will be observed, changes in VLF signals by parameters of the download and the ground changes as earthquake precursors was mentioned. Statistical analysis was performed with determined that had the earthquake before the changes in the phase of motion signals in this layer view.

After this the scientists try to affect the physical and chemical causes of the existence of a creator of various parameters

in ionosphere prior to the occurrence of great earthquakes that had the sample of existing hypotheses can be used in the article of plaints view (patinas and glen., 2003). He was imprisoned on the chemical and physical changes that occur in the shell is such a change in the level of radon gas in the home and the flower and finally radiation has increased the lead to changes in the parameters of ionosphere.

In the past ten years, the most important tool for GPS systems to the study of Physics of barley. In the ionosphere layer, the Electron density study and modeling tool free and TEC (linear integral satellite GPS receiver between the electron microscopic and density) is made, a single layer in a manner that production models for TEC is one of the typical products of the international IGNSS network. In this way, with the development of a network of local, regional and international GPS; study of ionosphere with adequate precision and with a more suitable density in comparison with the direct determination of density, electron microscopic technique is performed. Determination of density, electron microscopic and or at least determine TEC in this layer of the atmosphere with more information about its activities and to ionosphere. The importance of this information in spatial studies to the point is that the determination of the spatial density of the electron microscopic centers as one of the typical activities of these centers. In addition to the calculation of the correction of phase and group delay of the primacy of the waves, not only in determining the exact position of the recipients with a single-frequency, but also in the different stages of the processing of the data, such as GPS phase ambiguity solution of an inevitable process. Reconstruction of three dimensional electron microscopic density in this layer of the atmosphere to calculate TEC, computerized tomography method and the time delay and the aforementioned way possible.

With the development of these models was that the idea of using them in the study of the effects of large earthquakes on the ionosphere form. L and partners in their research in 2001, high frequency f2 layer critical Karolin the notice of ionusond and TEC from GPS receptors and thus the possibility of the use of this parameter for evaluation of earthquake precursors (l et al., 2003). Also, Abdullah and partners with the results of a survey in ionosphere modeling method of single-layer did, learned that the earthquake precursors in the earthquake, with more than 6 Magnitude to be good view (Abdullah et al., 2004). Wavelet analysis of colleagues and to assume the investigation in ionosphere precursors through the earthquake did Tums (assume et al., 1393). In this article it is attempted with the study of changes in ionosphere, to find a suitable for the expression of these continuity changes.

2 -VTEC Views

Of the two frequency GPS phase and code views of the carrier (a) L-band frequency in and of and are provided. Mathematical model of the geometric properties of these observations that the physical space and the enumerator is measured as follows:

Frequency L1:

$$P_1 = \rho + c(dt - dT) + d_{orb} + d_{trop} + I + b_{p1} - B_{p1} + d_{mult/p1} + \varepsilon(P_1) \quad (1)$$

$$\Phi_1 = \rho + c(dt - dT) + \lambda_1 N_1 + d_{orb} + d_{trop} - I + b_{\Phi 1} - B_{\Phi 1} + d_{mult/\Phi 1} + \varepsilon(\Phi_1) \quad (2)$$

Frequency L2:

$$P_2 = \rho + c(dt - dT) + d_{orb} + d_{trop} + \gamma I + b_{p2} - B_{p2} + d_{mult/p2} + \varepsilon(P_2) \quad (3)$$

$$\Phi_2 = \rho + c(dt - dT) + \lambda_2 N_2 + d_{orb} + d_{trop} - \gamma I + b_{\Phi 2} - B_{\Phi 2} + d_{mult/\Phi 2} + \varepsilon(\Phi_2) \quad (4)$$

Where:

$$I = 40.3\frac{TEC}{f_i^2} \quad (5)$$

$$TEC_{\Phi} = \frac{f_1^2[(\lambda_1\Phi_1 - \lambda_2\Phi_2) - (\lambda_1 N_1 - \lambda_2 N_2) - b_i - b^p]}{40.3(\gamma - 1)} \quad (6)$$

Also, the quantity of TEC could be directly achieved overnight observation distance:

$$TEC_R = \frac{f_1^2[(P_1 - P_2) - B_i - B^p]}{40.3(1-\gamma)} \quad (7)$$

γ The frequency ratio of two squares as

$$\gamma = (\frac{f_1}{f_2})^2 = (\frac{77}{60})^2 \quad (8)$$

Due to the existence of two phase ambiguity and in equation (6) of the TEC, which shall be calculated from the relative quantity of phase observation. In contrast, the cause of which is in pseudo code, distance views of ambiguity there is no phase, achieved the absolute value of the TEC is quantity. Despite this, the TEC quantity obtained from the carrier wave phase observations due to higher accuracy of carrier phase observations views more carefully than the code, with TEC obtained from observations of the code. On the other hand if the waves, continuous and deterministic system in the temporary without (a mutation phase), two phase residual ambiguity mentioned are fixed. This can be performed with the formation of a suitable composition of the equations (6) and (7) to the absolute amount of TEC approved estimation accuracy better than the value resulting from the TEC views the code. This so-called TEC rates softened. For this work in the first step of the amount of difference between two TEC views the code and be calculated in every phase of the epoch:

$$\Delta TEC_n = TEC_{R,n} - TEC_{\Phi,n} \quad (9)$$

The values for frequency and satellite receiver inside the Bayes during a period of several days, a steady, relatively. After calculation ΔTEC_n of the equation (9), absolute and relative offset between the TEC with the value obtained from equation (6). Therefore, $TEC_{SM,N}$ the absolute value of the amount of Estimation has been determined from the following relationship TEC:

$$\Delta TEC_N = \frac{1}{N}\sum_{n=1}^{N}\Delta TEC_n \quad (10)$$

$$TEC_{SM,N} = TEC_{\Phi,N} + \Delta TEC_N \quad (11)$$

To get the value of the electron content in the ionosphere zenith function can be used as the picture below:

$$VTEC = M \times TEC_{SM,N} \quad (12)$$

We found that:

$$M = \frac{1}{\sin(elev)} \quad (13)$$

3 -The Effects of Solar Activities

Since the radiation of the Sun, including the influential factors on the ionosphere of the Earth and the study of changes in the effect of the earthquake at the ionosphere with some complexity, along with the effect of magnetic storm must studied ionosphere layers. Figure (1) indicating the period of solar activity by 2020.

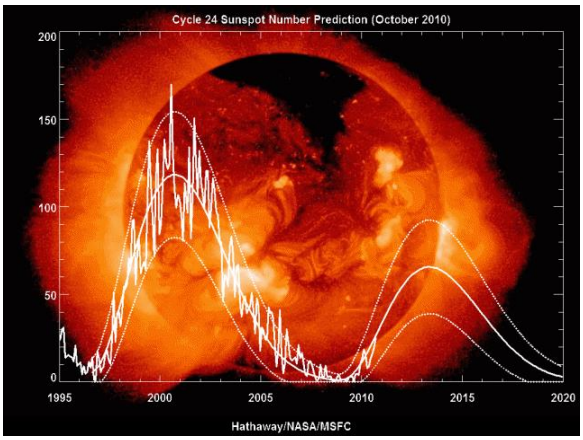
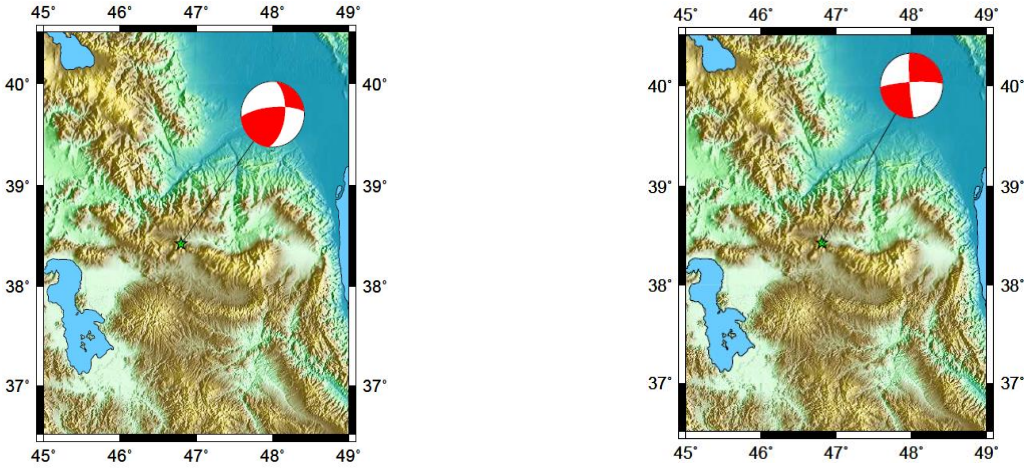


Fig. 1. How solar activities of the period 1995-2020

Its activities and the role of the main and fundamental role in the dynamic space. High solar activity accordingly creates major changes in density, electron microscopic and ionosphere. This is because of an increase in solar radiation increasing Photosynthesis. Similarly reduce the solar radiation decreases the available activities at ionosphere. For this purpose use the Kp maps. Indeed, Kp maps of average corrosion measured data with the help of K is calculated, magnetometer. Corrosion Kp represents maximum entropy in the geomagnetic field of the Earth, which is created by the activities of the Sun, and for every three hours and some calculated between zero to nine for the correct number to itself.

4 -Double Earthquakes Varzaqan-AHAR

AHAR earthquakes Varzaqan-couples range in East Azarbaijan in the North West of Iran-Alborz and geological zone of Azerbaijan. Based on existing reports two successive earthquake, are due with the Mw=5.6 and in the West with a great second and AHAR Mw = 3.6 in AHAR County from 21 Mordad 1391 reads (11 August 2012) crowd. According to the report of the Institute of geophysics, University of Tehran, facing the center of these events were in the points with coordinates 43.38 North latitude and 81.46 degrees East longitude and degrees 46.38 degrees north latitude and coordinates 84.46 degrees East longitude. The focal mechanism also raised for both the earthquake as along. This earthquake occurred in the area of the active fault no identification yet.



(a) (b)

Fig. 2. Location and focal mechanism couples the earthquake varzaqan-Ahar, figure (a) is related to the earthquake with great torque = 5.6 Mw and figure (b) relating to the earthquake with great torque = 3.6 Mw (information retrieved from the site Institute of Geophysics University of Tehran)

5- The Results of The Analysis

Study and evaluation of the effect of the direction of the earthquake on the changes in the overall amount of time-spatial ion-electron content observations of the local network, the heart of Azerbaijan, has been used. Measurement is used corresponding to the month of August in the year 2012. 12 days of the year 2012 (219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229 and 230) has been applied to the analysis. The pattern of distribution of these stations in the form of (3) has been shown.

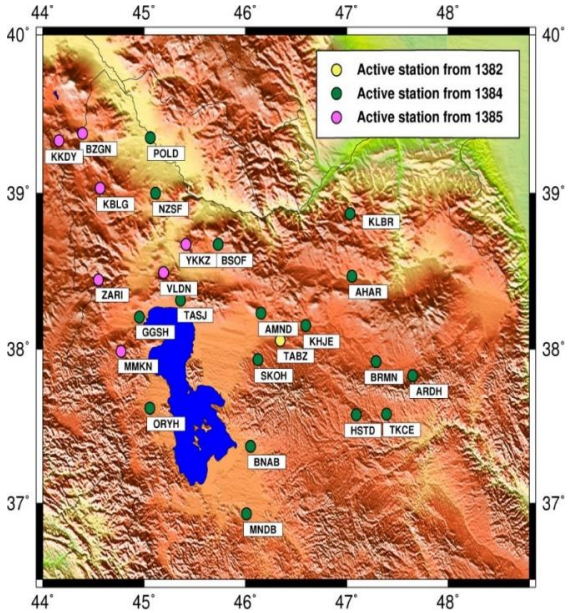


Fig. 3. Spatial distribution pattern of stations used in this article are derived from the Organization's Web site, surveying the country

Index of solar activities for the 12 days of the site (http://www.spaceweatherlive.com) download that figure 4 indicating how changes in this index.

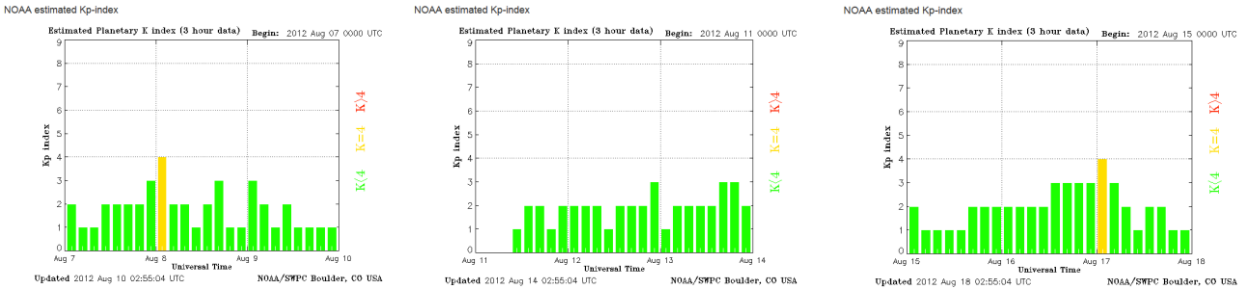
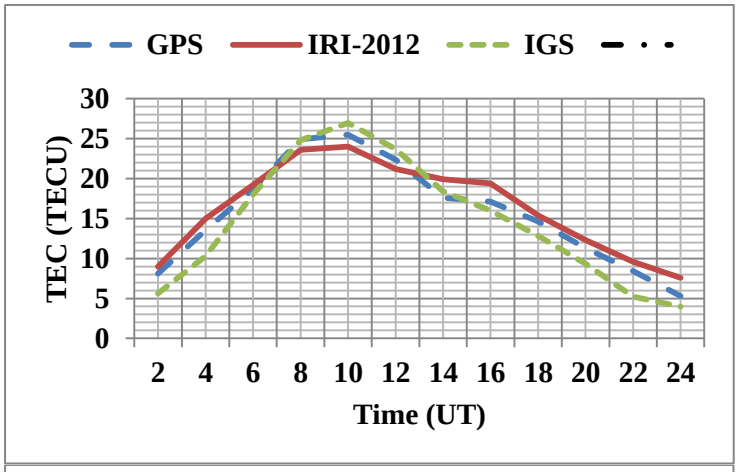


Fig.4. Kp index for changes in how the 12-day case study in this paper

Overall direction of the electron content of the study and the evaluation of the accuracy of the values of the global network of GPS VTEC, IGS and the global reference model IRI2012 output is used. Comparison of content obtained from electron microscopic amounts of the three models is shown in Figure 5.

DOY#219



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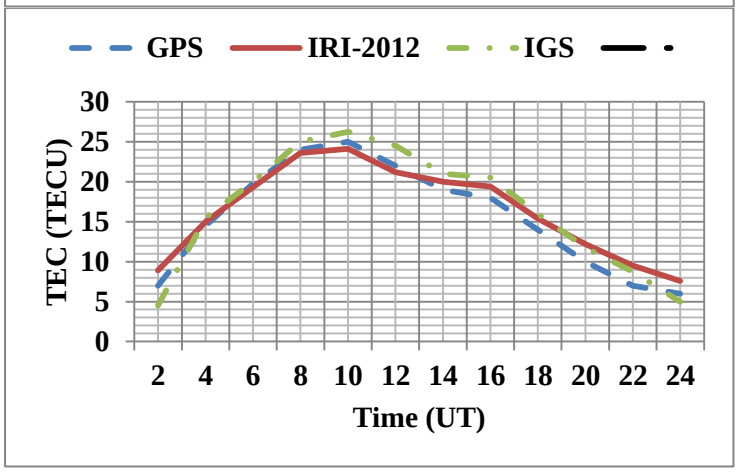

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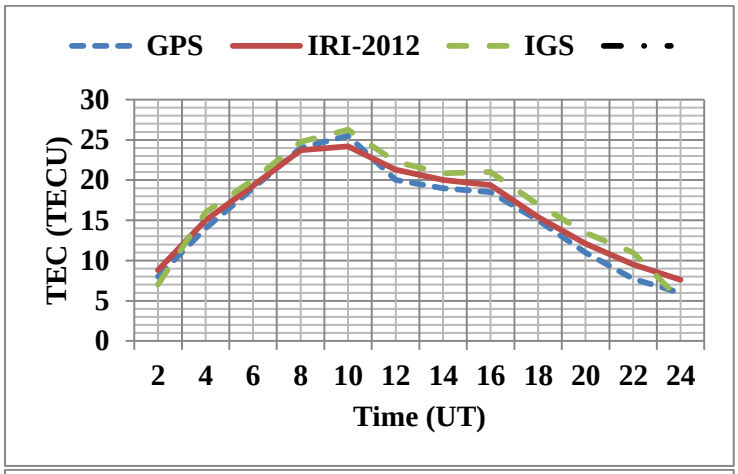

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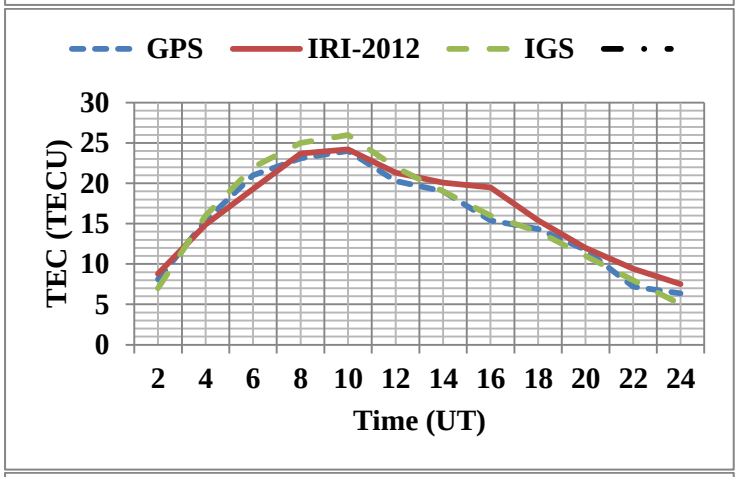

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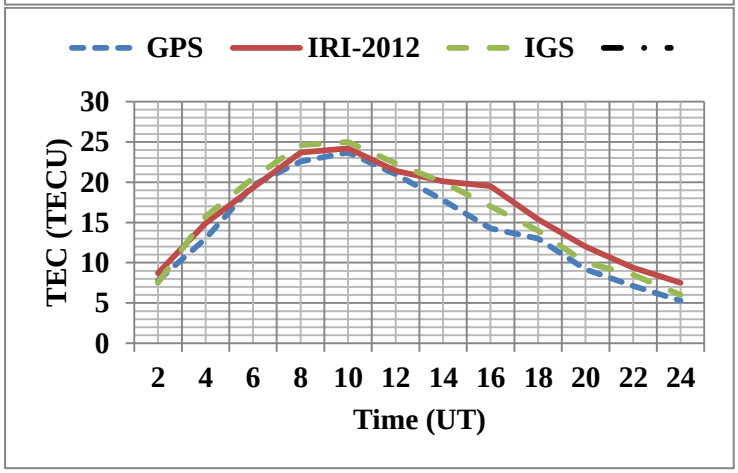

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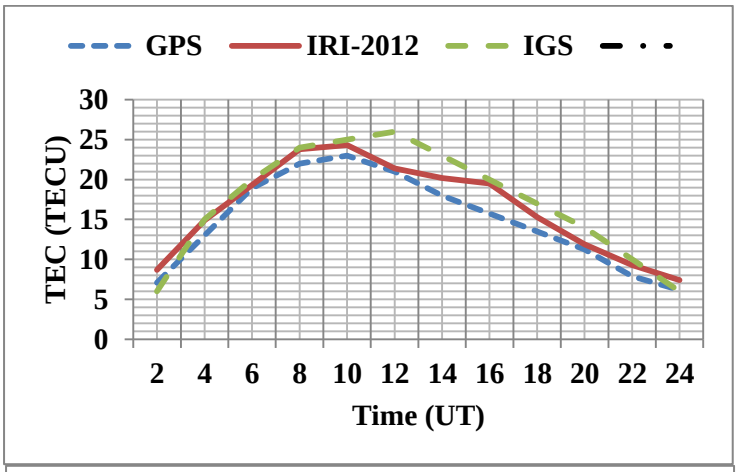

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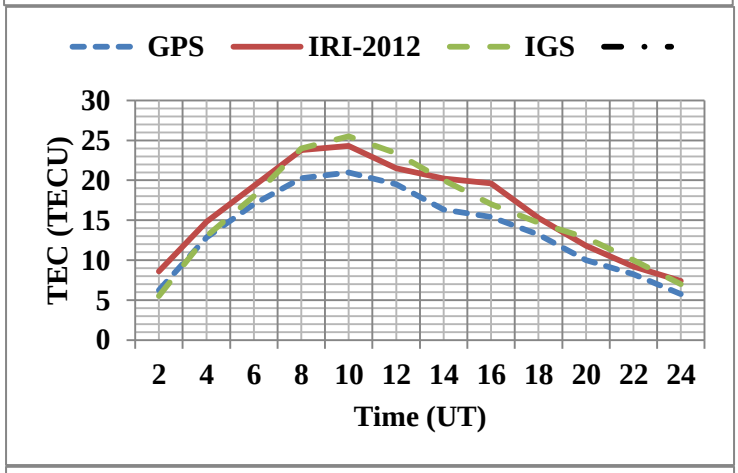

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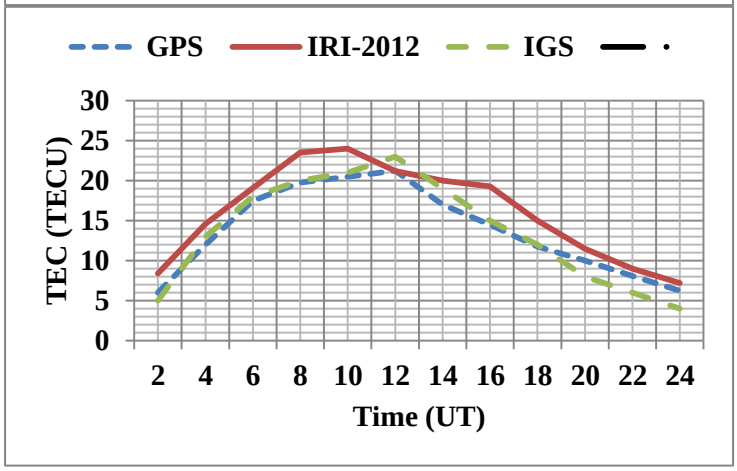

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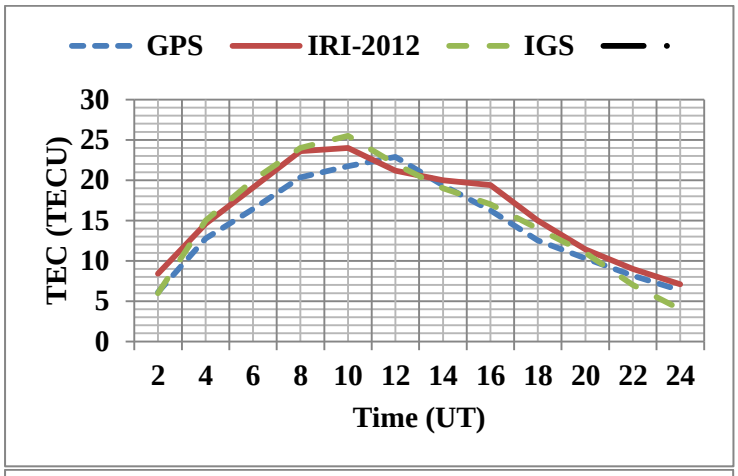

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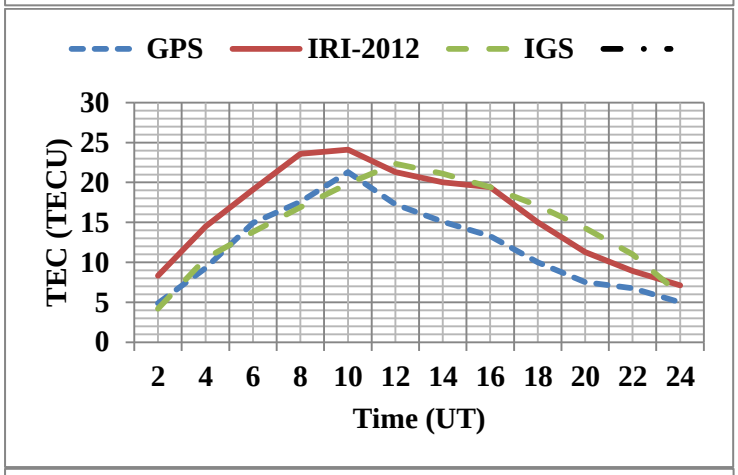

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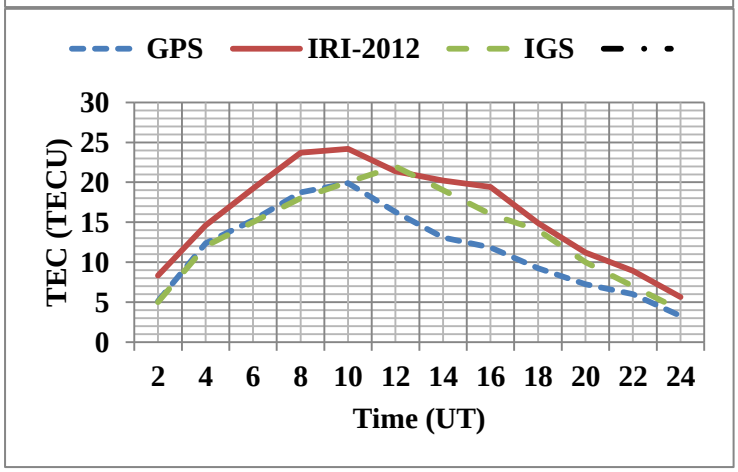

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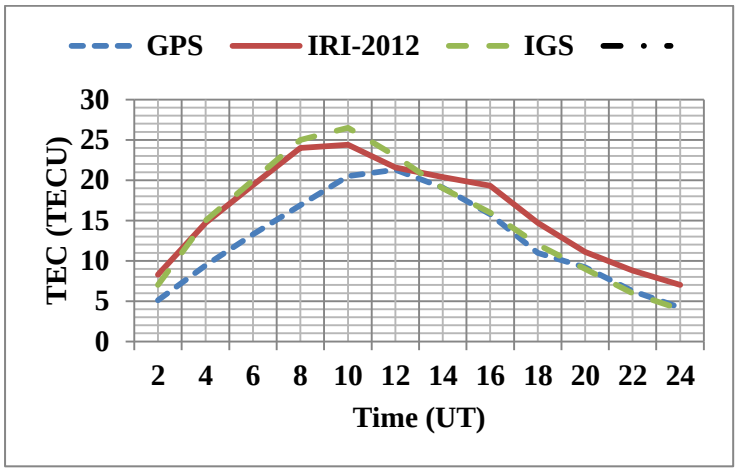

Fig.5. A comparison of changes in the value of the overall quality of the electron content obtained from GPS, the global reference model and output the global IGS network at 12 consecutive days of the year 2012

According to the results of Figure 5, we can clearly see that the amount of overall content is obtained with electron microscopic changes in the length of day and night. To view the changes in the overall content of the better electron ionosphere AHAR which is close to the station, the location's earthquake and the variation of this station for the study. The pattern of these changes is shown in Figure 6.

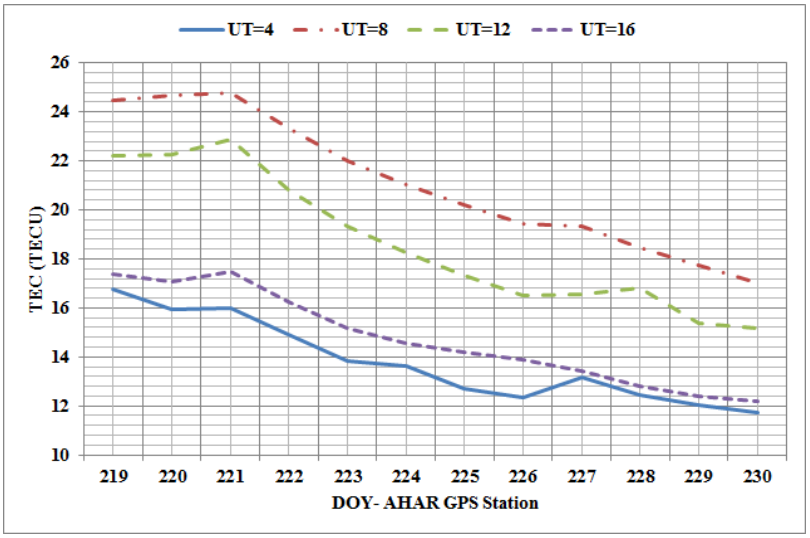

Fig.6. The pattern of changes in the value of the overall content of the electron ionosphere in AHAR for 12 consecutive days of the year 2012

According to figure 6 clearly observed the electron content of the overall amounts of girded ionosphere from 5 days prior to the occurrence of the earthquake has reduced progressively. Can be concluded that with the overall amount of time changes the electron content can be obtained from the use of markers as before.

6- Conclusion

In this article, the size of the local network of GPS stations expansion study of precursors to Azerbaijan the amount of electrons in Earth Quake ionosphere overall content was used. Because of the fact that two of the earthquake in the region in the year 2012 only this attachment area as the study area was selected. The measurement of GPS stations were used to calculate VTEC. Also, for evaluating the authenticity of the results obtained for the reference model of the VTEC and the global network of the world 2012 also IGS output were used. Comparison of the results should be taken of the GPS. According to the results, which were conducted for AHAR station was shown a few days before the earthquake changes the electron content in the overall amount of ionosphere will be created. These changes until a few days after the earthquake, also continues.

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